

Imaging Ladar ATR / ATI Workshop

Research Institute for
Optronics and Pattern Recognition

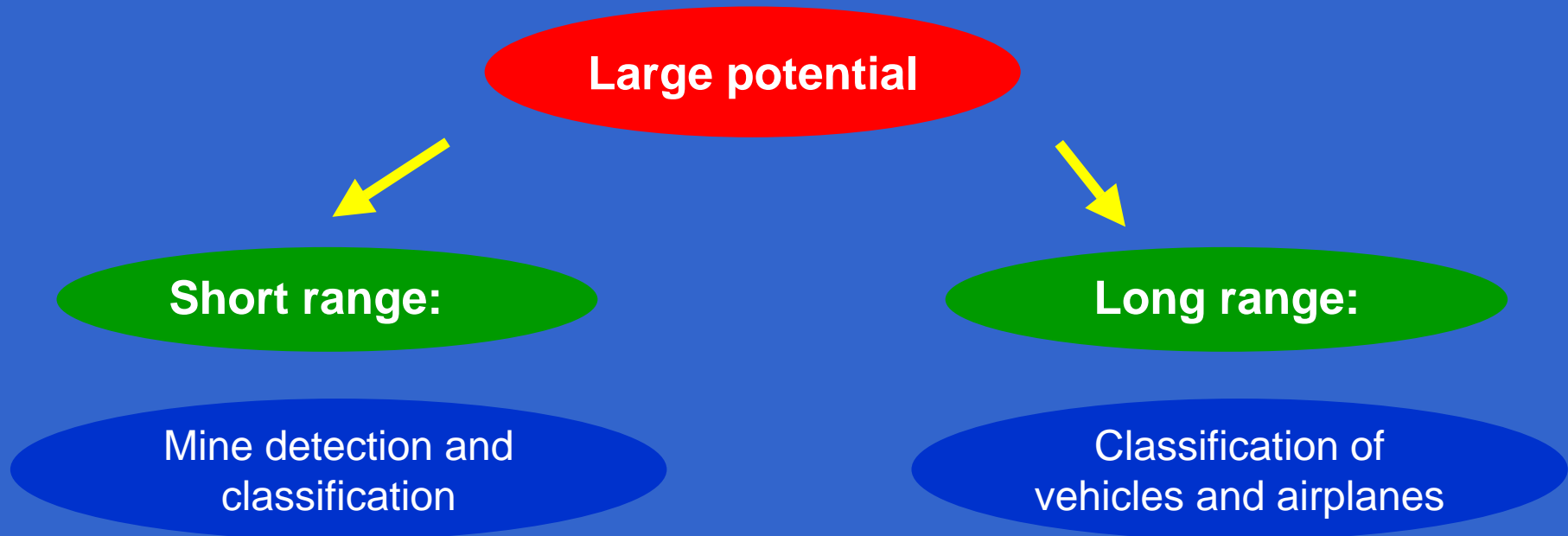
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Potential of Target Classification by Remote Surface Vibration Analysis Using Coherent Laser Radar Systems

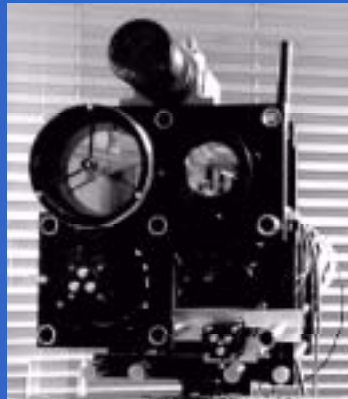
P. Lutzmann, M. Hebel

Ettlingen
27-29 October 2003

Remote Vibration Sensing



- 632 nm (HeNe-laser)
- 10.6 μm (CO₂-laser)
- 1.54 μm (Erbium fiber laser)
- 2 μm (Holmium laser)



**10.6 μm - coherent laser radar
(vibration sensor)**

Laser source: 10.6 μm - waveguide laser

Transmitter:

Output power 8 W
Aperture diameter: 50 mm

Receiver:

Aperture diameter 100 mm
Field of View 0.4 mrad

HgCdTe quadrant detector 225 x 225 μm^2
(element size: 100 x 100 μm^2 , space: 25 μm)

Intermediate frequency: 100 MHz
one AOM (40 MHz) in the transmitter beam
one AOM (100 MHz) in the LO beam



**1.54 μm - coherent laser radar
(vibration sensor)**

Laser source: 1.54 μm - erbium fiber laser

Transmitter:

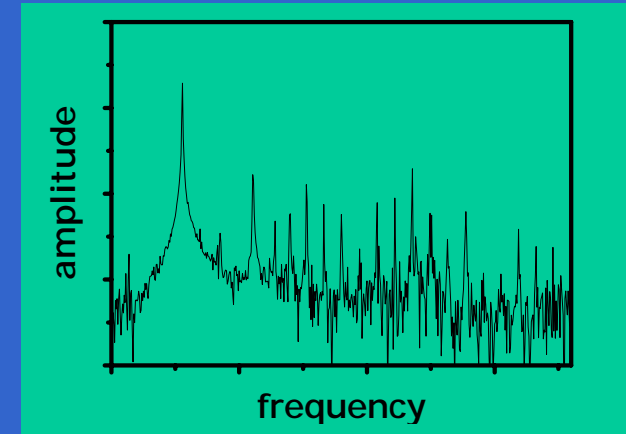
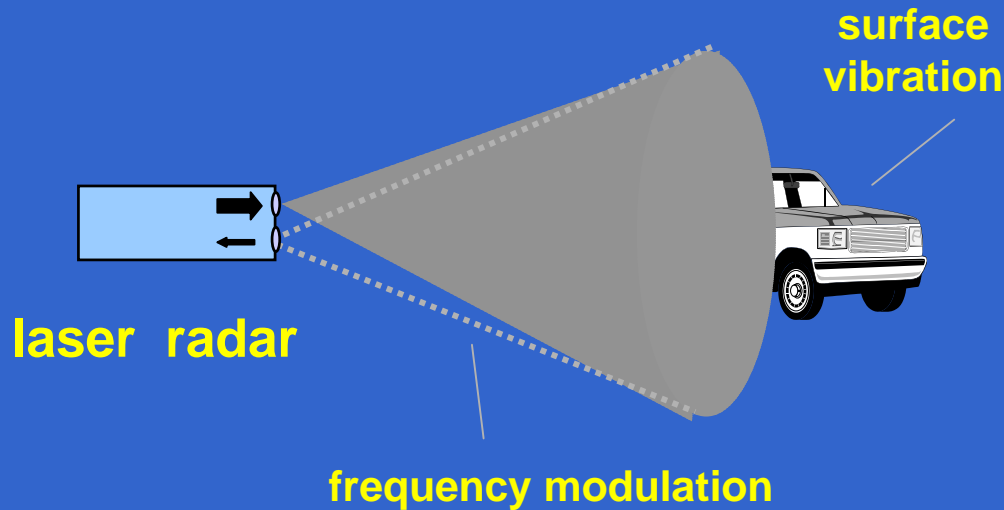
Output power 0.8 W
Aperture diameter: 50 mm

Receiver:

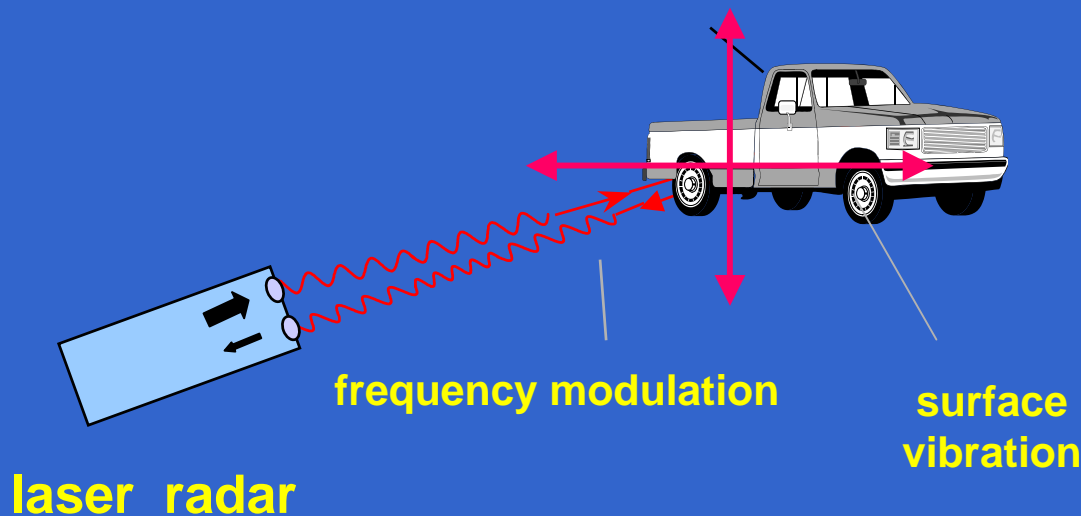
Aperture diameter 50 mm
Field of View 75 μrad
InGaAs photodiode 100 x 100 μm^2

Intermediate frequency: 60 MHz
one AOM (40 MHz) in the transmitter beam
one AOM (100 MHz) in the LO beam

Vibration Signatures: Spatially Unresolved / Resolved



spatially unresolved vibration signature



spatially resolved vibration signature at 28 Hz

2D – Vibration Signatures ($\lambda = 1.54 \mu\text{m}$)



28 Hz



108 Hz



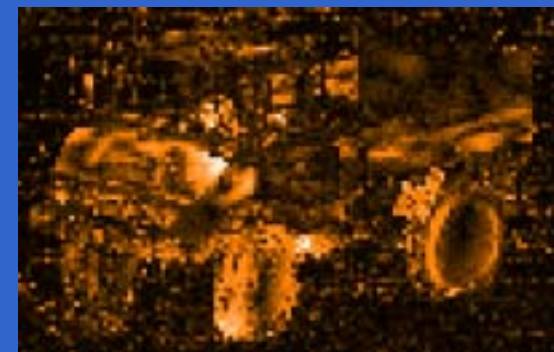
55 Hz



135 Hz

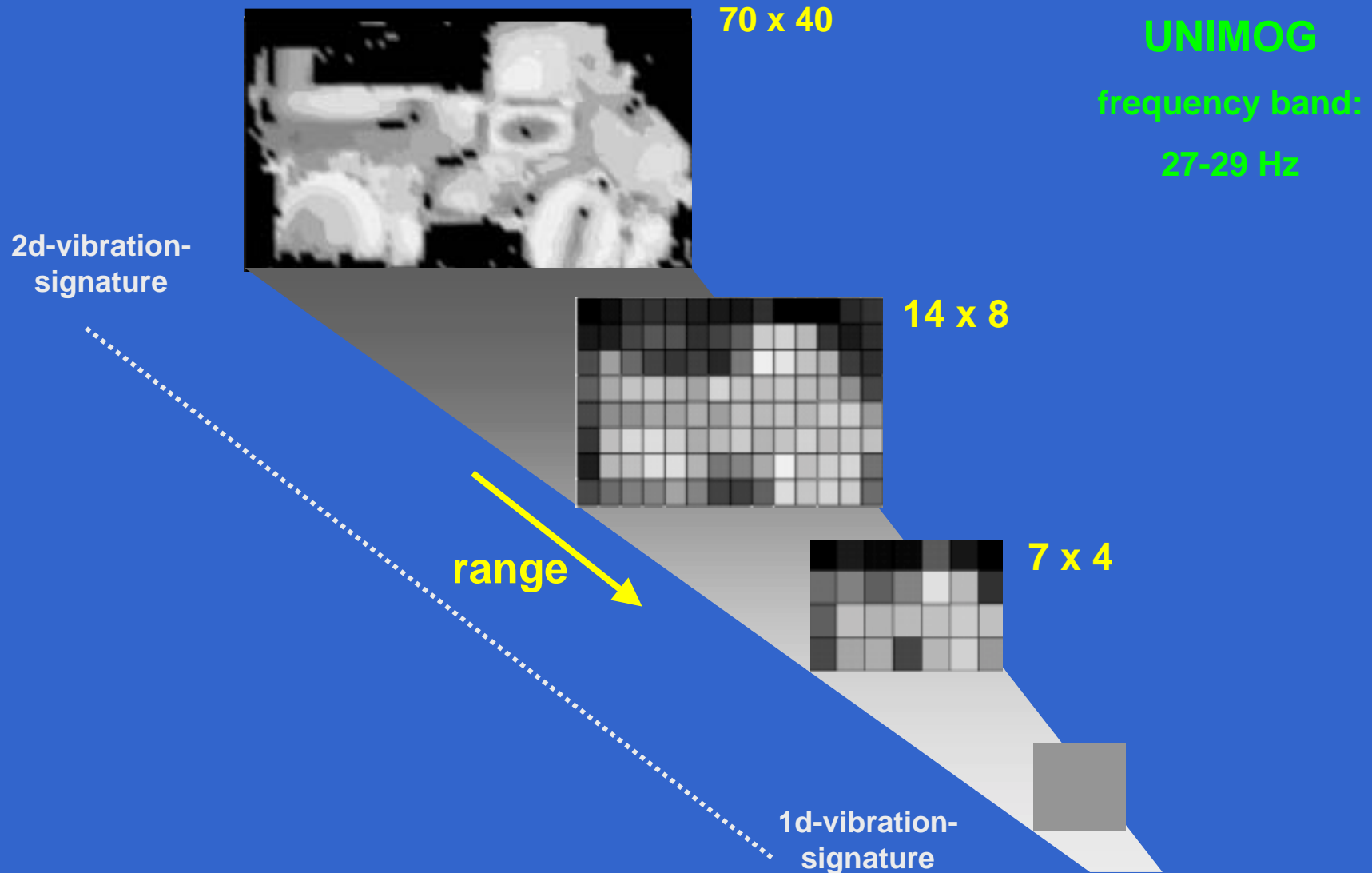


80 Hz



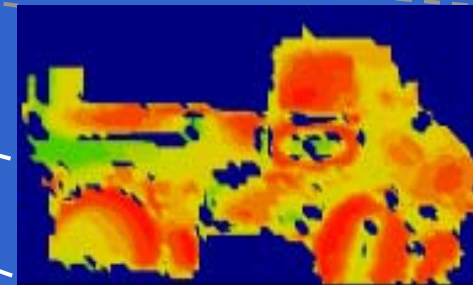
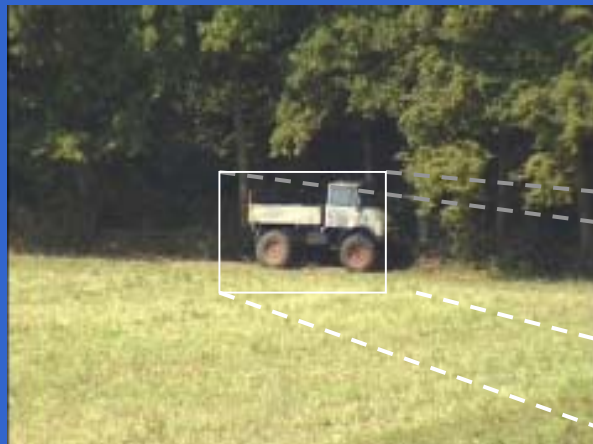
163 Hz

Reducing of Spatial Resolution

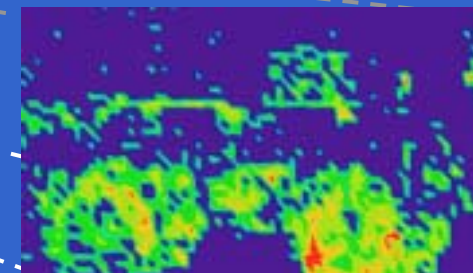


2D-Vibration Signature of Camouflaged Target

CO₂ laser radar / $\lambda=10.6 \mu\text{m}$



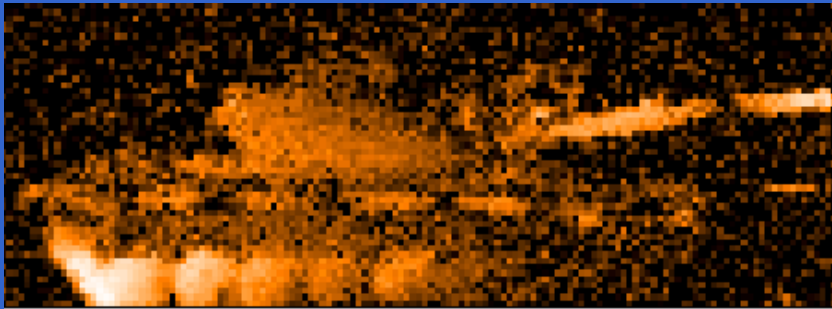
vibration
amplitude



vibration
amplitude

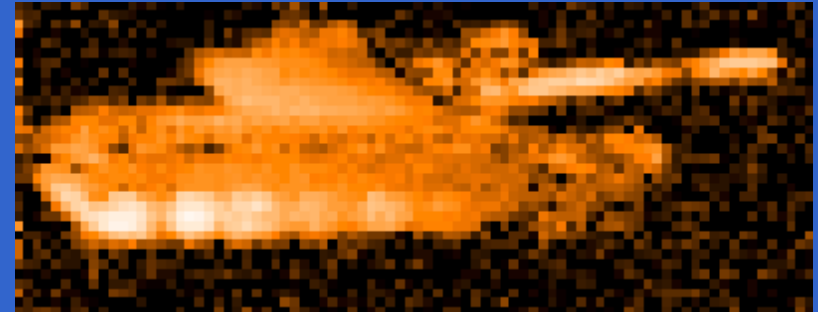
M60: 2D-Vibration Signature

10.6 μm / FGAN-FOM



number of pixels: 90 x 45

1.5 μm / TNO-FEL



number of pixels: 84 x 33

**2d-vibration signature of M60
at the main frequency of 30.5 Hz**

- strong turbulence condition ($C_n^2 \approx 10^{-13} \text{ m}^{-2/3}$)
- range of 1.3 km

2D-Vibration- und Reflective Signature at 1.5 μm (TNO-FEL)

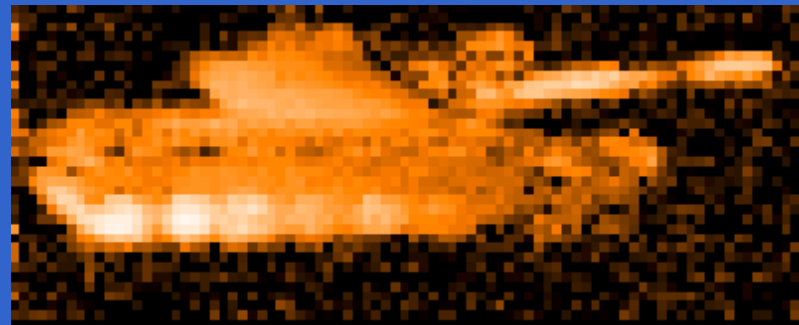


M60
(visual image)

2d-vibration signatur

number of pixels: 90 x 45
range: 1.3 km

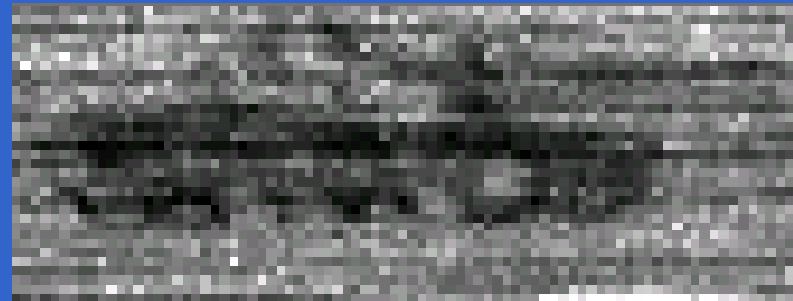
$$(C_n^2 \approx 10^{-13} \text{ m}^{-2/3})$$



vibration
amplitude

reflective signature
number of pixels: 90 x 45
range: 1.3 km

$$(C_n^2 \approx 10^{-13} \text{ m}^{-2/3})$$



reflectance

Following Data Sets are Available for Common Data Base (NATO SET-RTG45):

2d-vibration-signature:

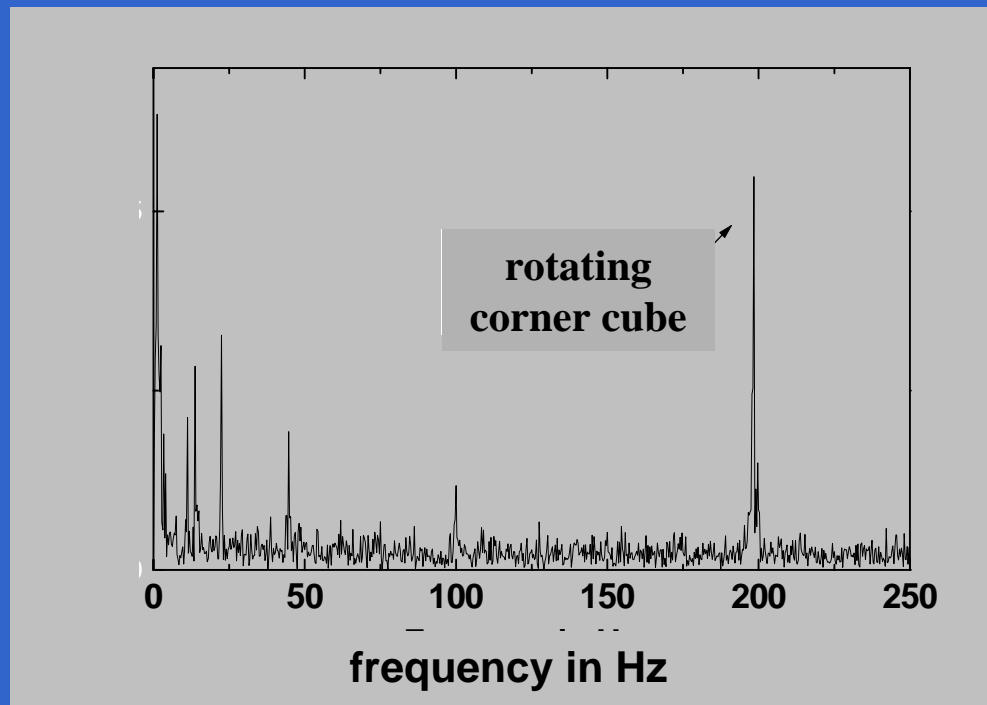
- **Small truck (UNIMOG)**
Raw data (IF data) / 1.2 GBytes
10.6 μm and 1.54 μm – laser radar
pixel number: 90 x 45
range: 150 m
- **Tank (M 60)**
Raw data (IF data) / 1 GBytes
10.6 μm – laser radar
pixel number: 112 x 75
range: 1300 m
(camouflaged and uncamouflaged)

1d-vibration-signature:

- **6 different types of land vehicles (several of the same type)**
FFT- data
range: 860 m, 1200m, 3200 m
driving condition: idling, low speed

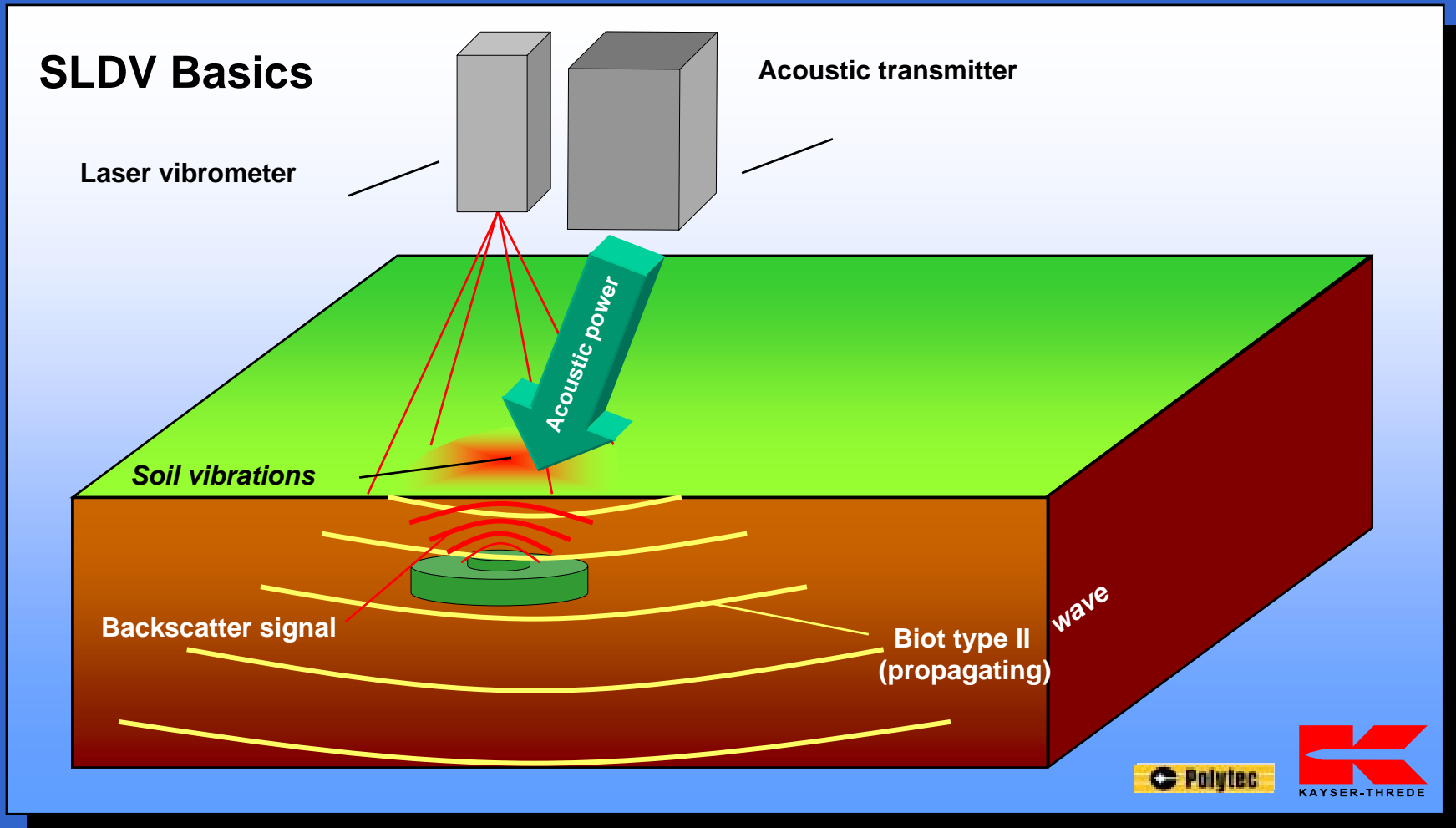
To improve the identification of friendly targets:

**Self-induced coded vibration frequency within
the vibration signature of the target
- changeable by code-of-the-day-**

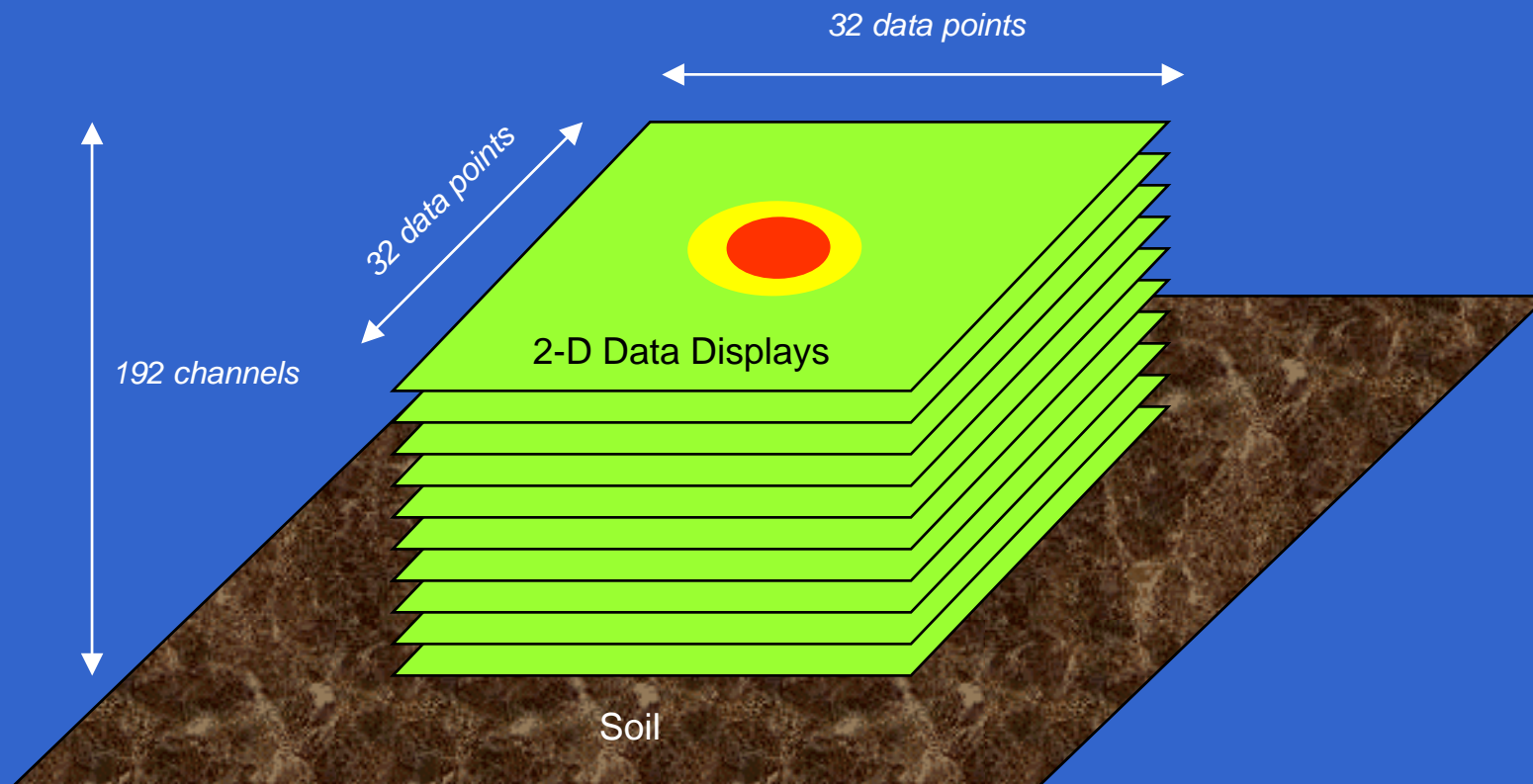


target : VAB
engine condition: idling
range: 1500 m

An approach towards the detection of buried land mines using vibrometry data



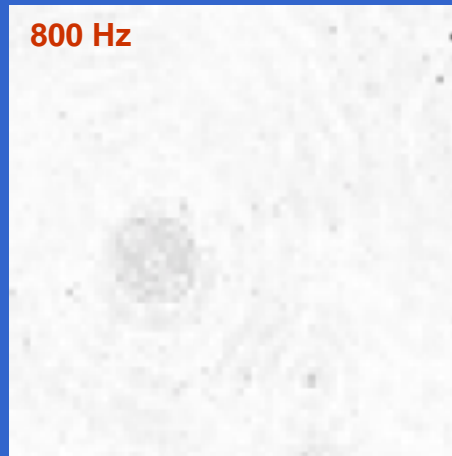
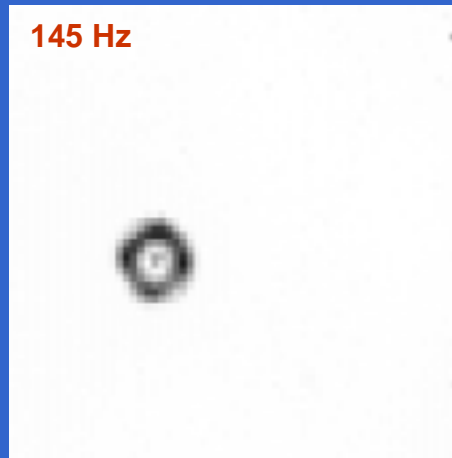
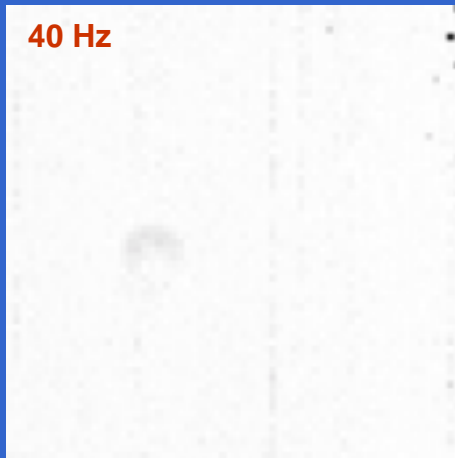
Spectral 3D Structure of SLDV Data



Amount of data in this sample:
 $32 \times 32 \times 192 \text{ [points}^2 \cdot \text{channels]} = 196.608$

■ Maximum
 ■ Minimum

Data set obtained during a field campaign at the
Joint Research Centre Ispra - Italy



Raw Data (Velocity of Soil Vibration)

Tested Area:

Type: Sand

Area: 0.25 m²

Grid: 64 x 64 points

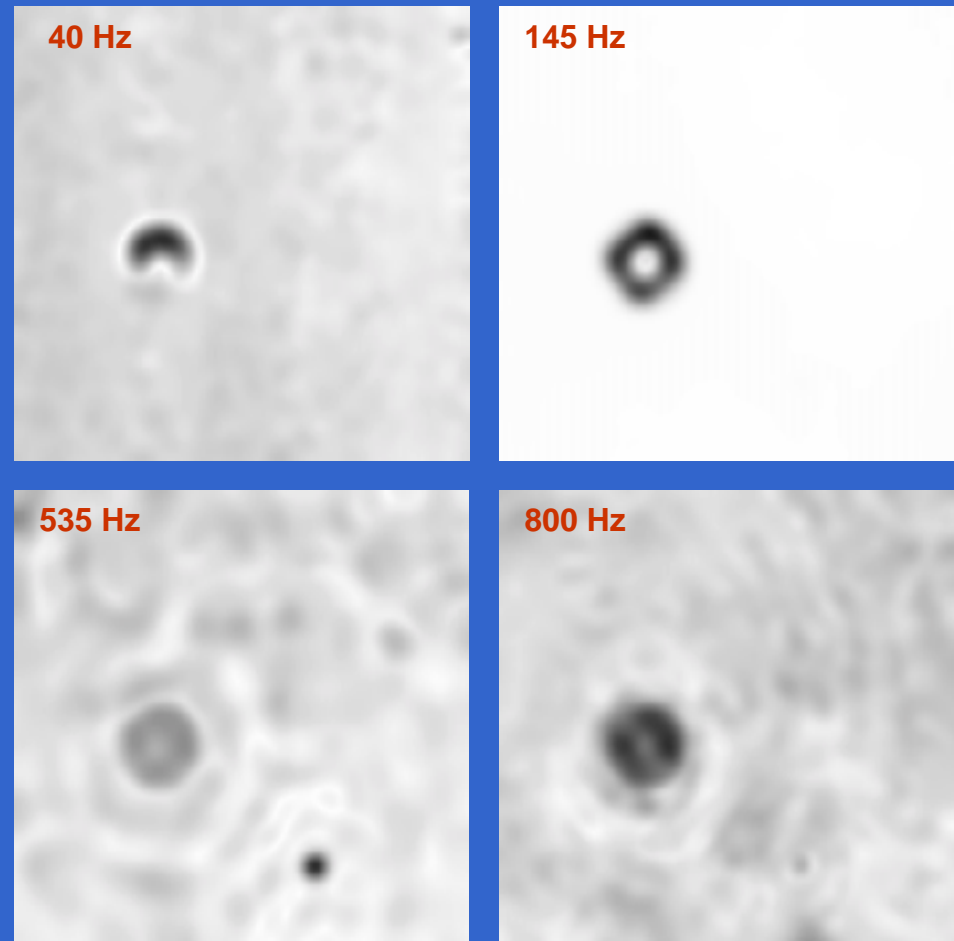
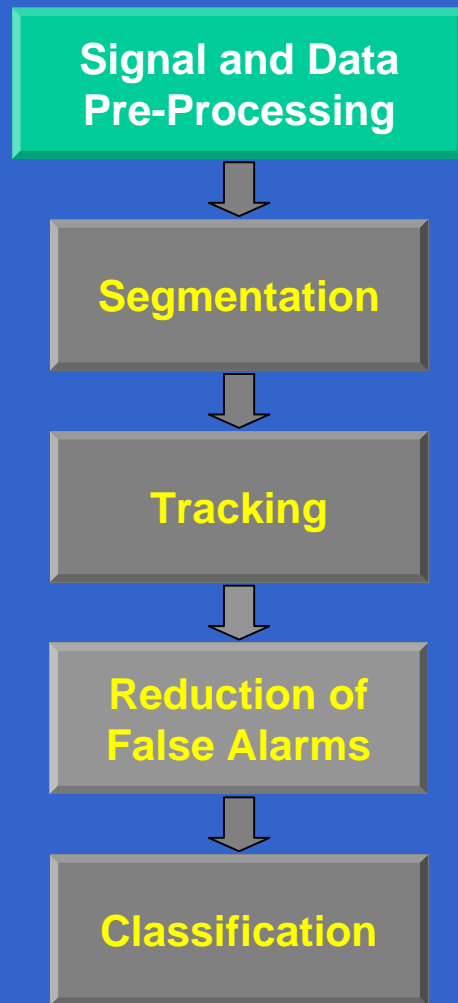
Frequency: 40 Hz – 1000 Hz

Buried Object:

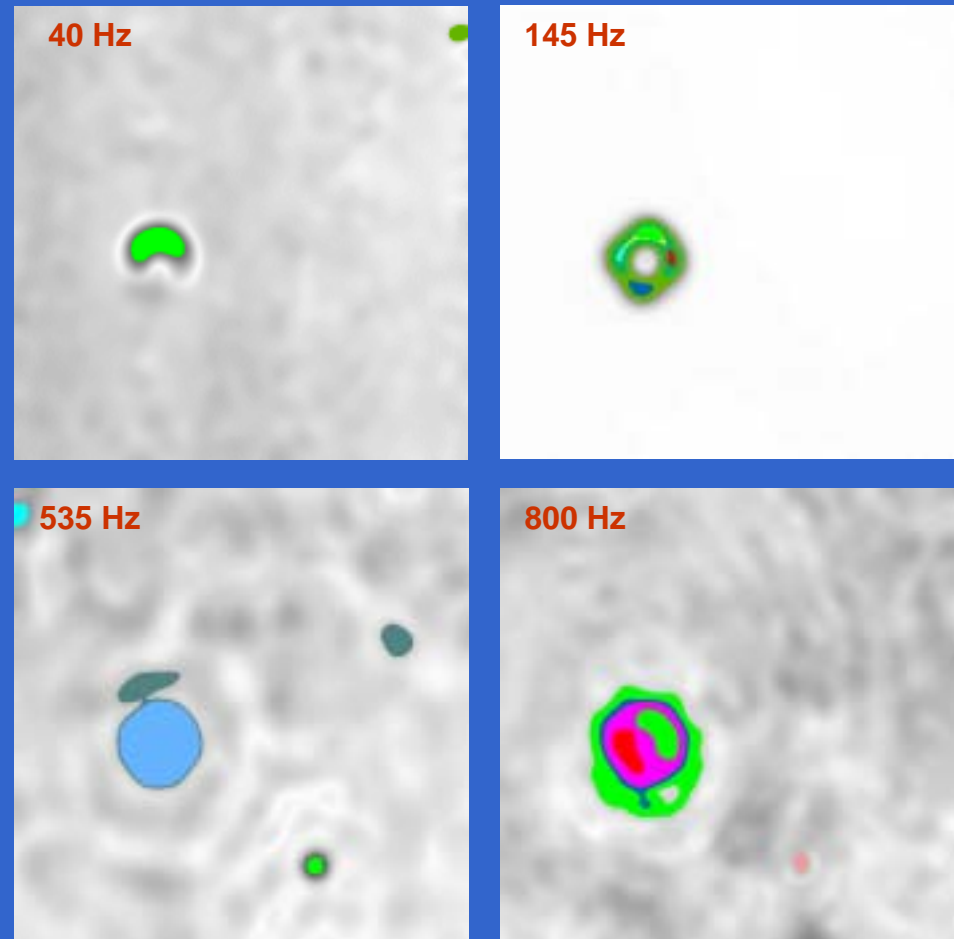
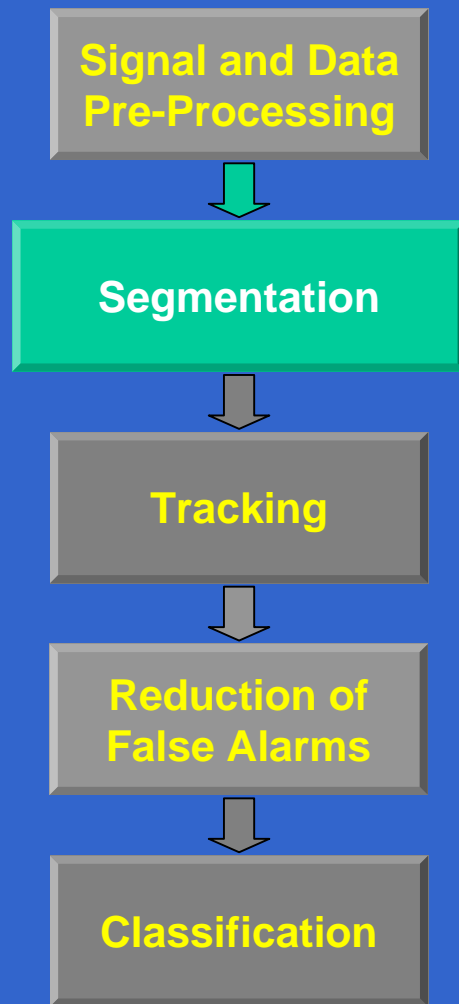


Depth: 3 mm

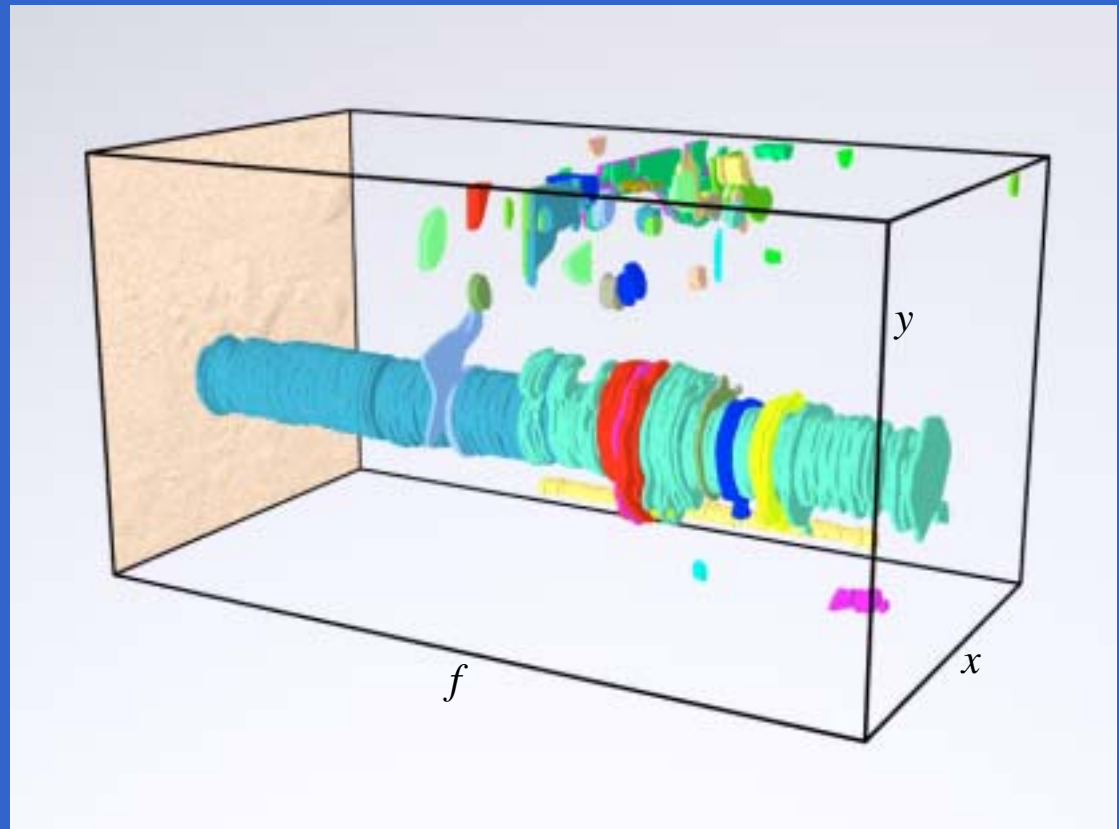
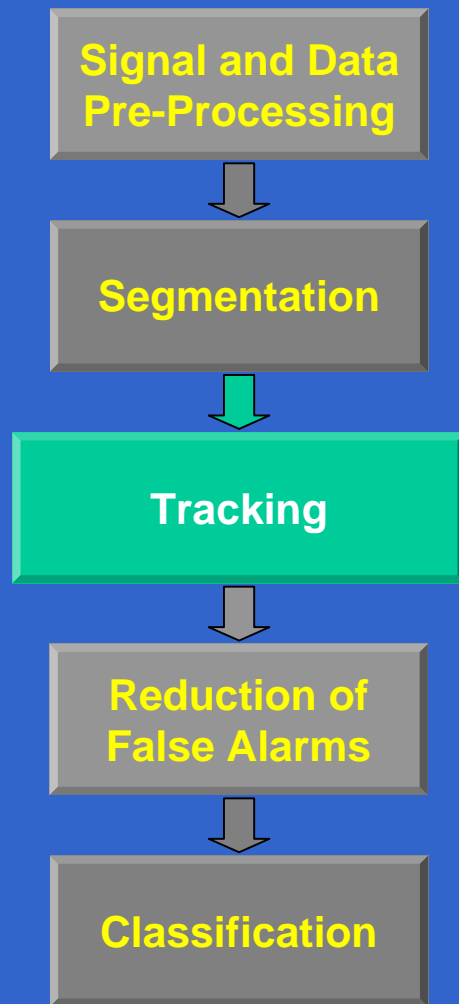
Frequency: 40 Hz – 1000 Hz



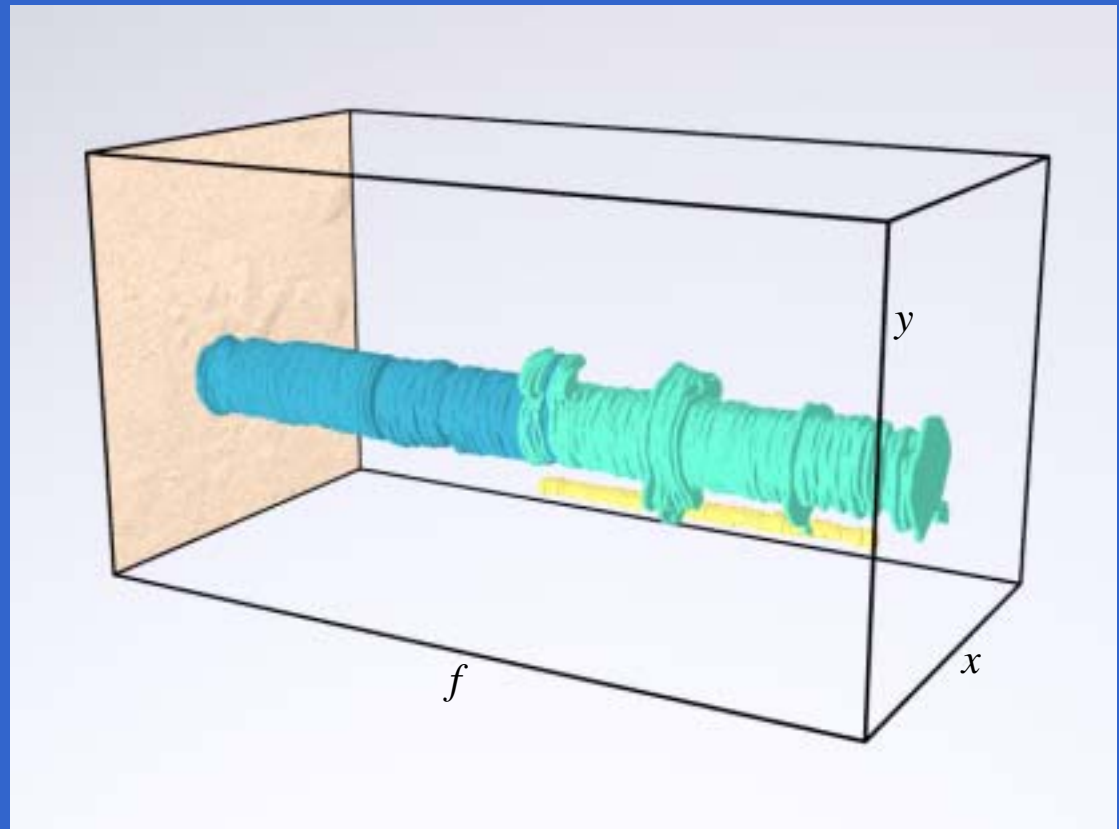
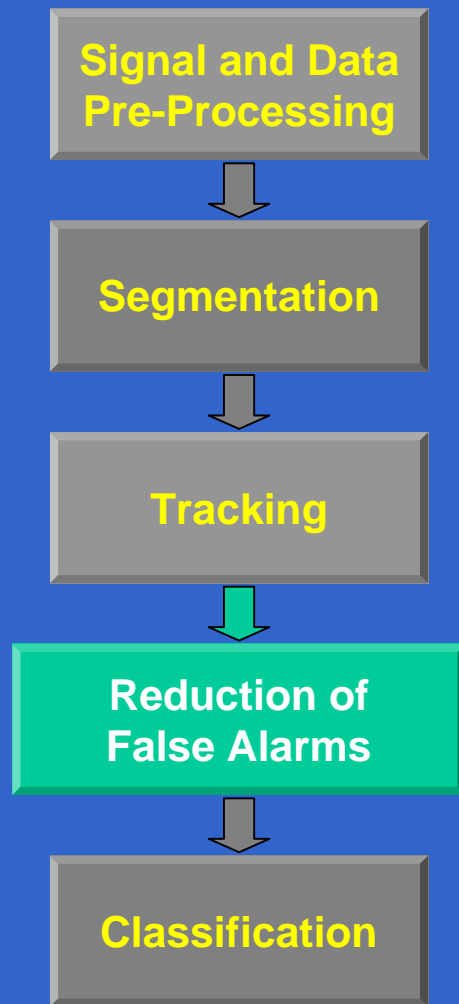
Pre-Processing (eg. Gaussian Low Pass Filter)



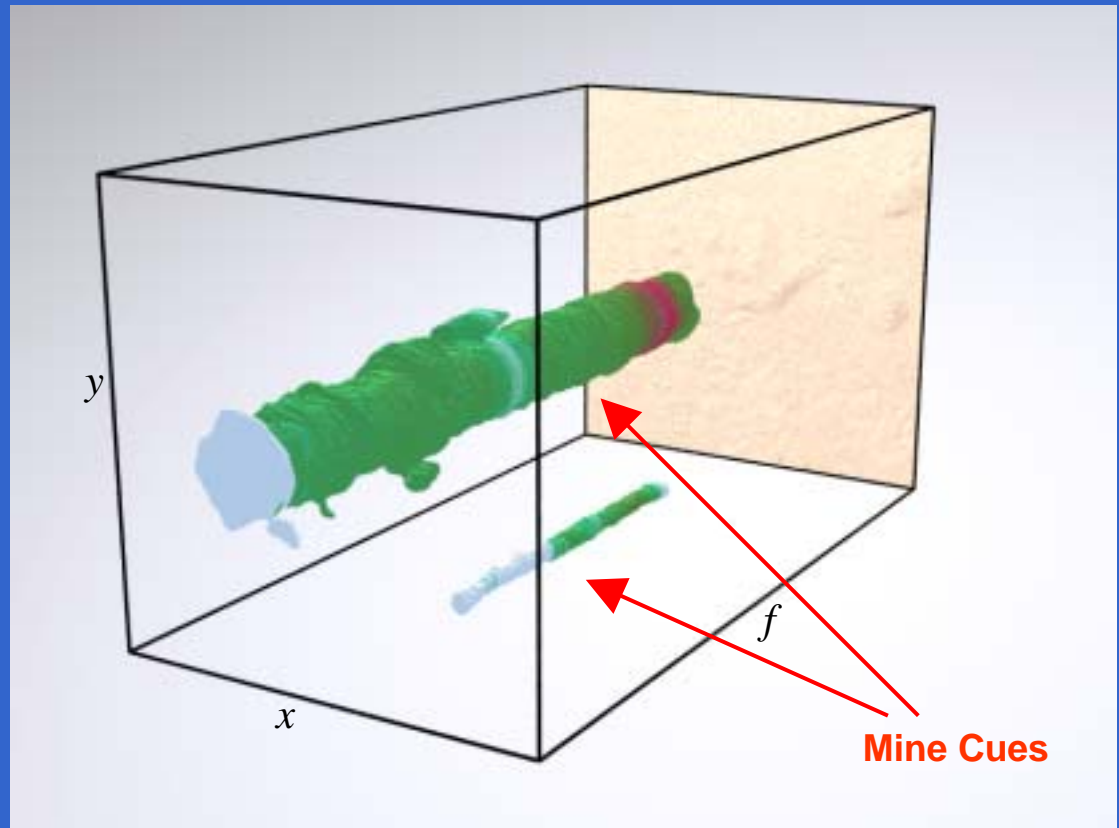
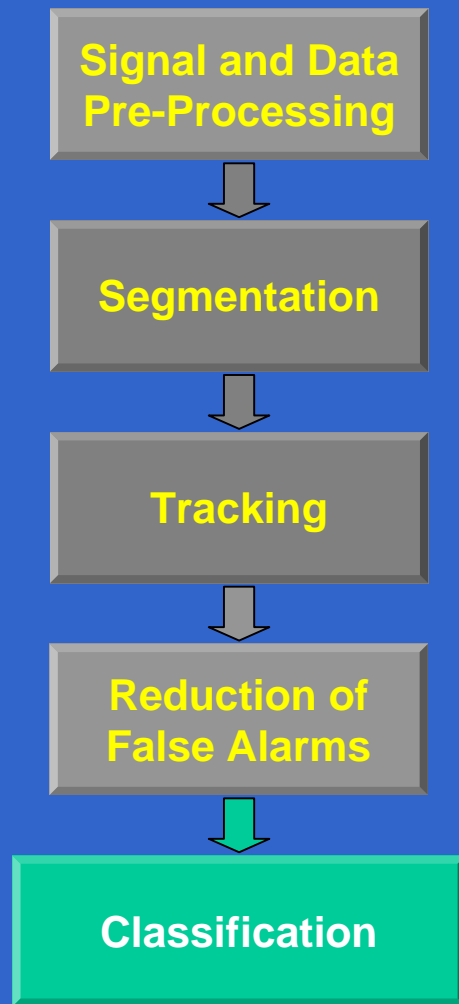
Segmentation by Multi Threshold Analysis



3D-Representation of
Objects with Stability in Frequency

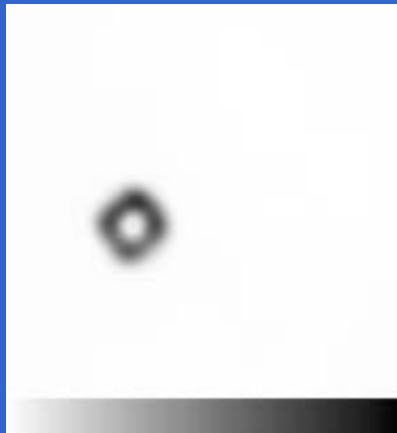


Reduction of False Alarms
(Object Size, Stability of Behavior)

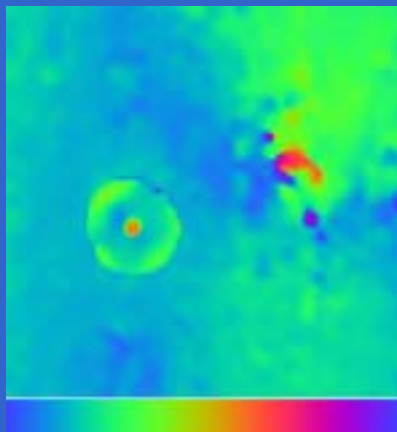


Classification
(Features)

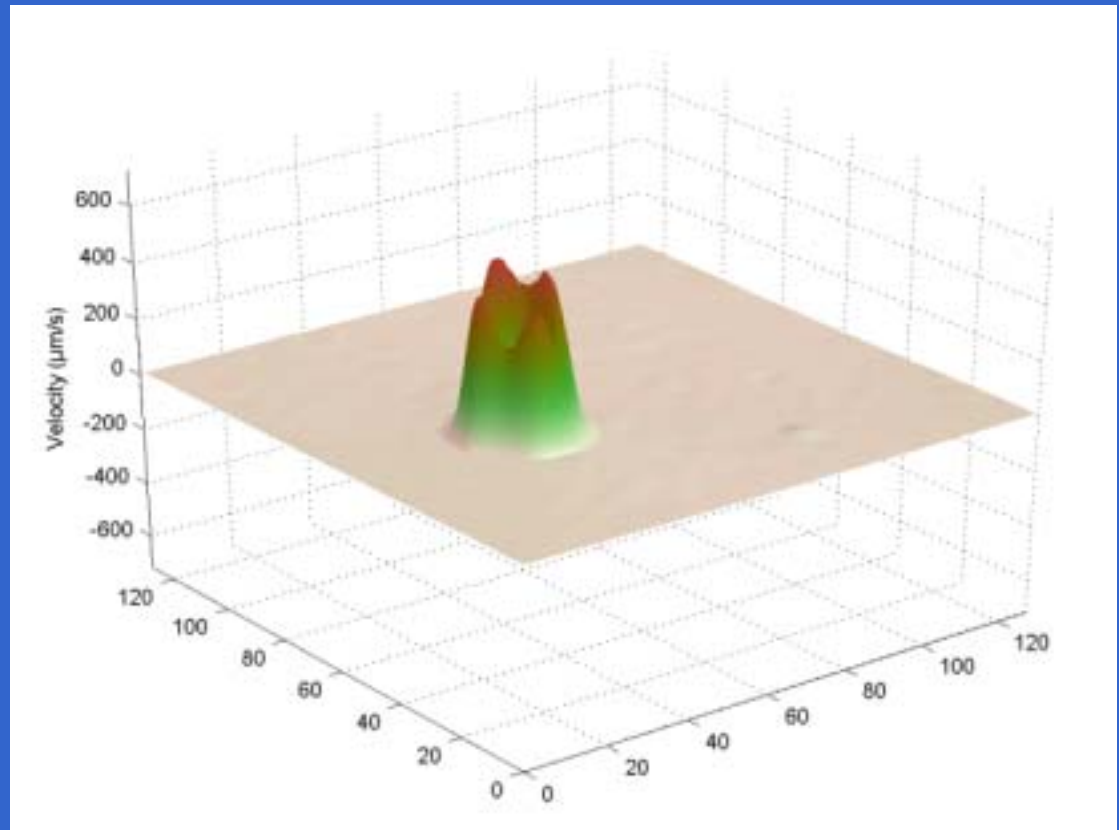
Actual activities: Inclusion of phase information



Intensity

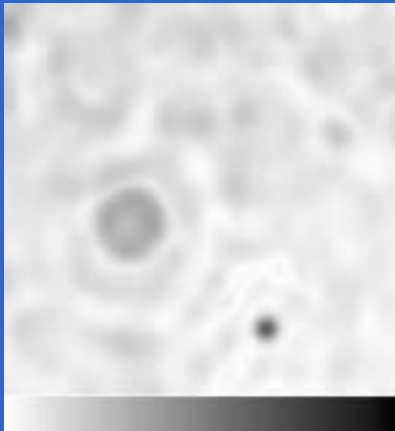


Phase

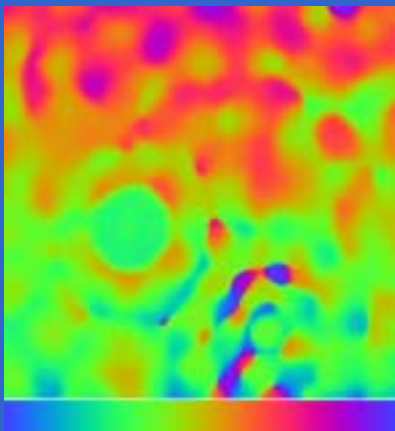


Visualization of soil vibration at 145 Hz

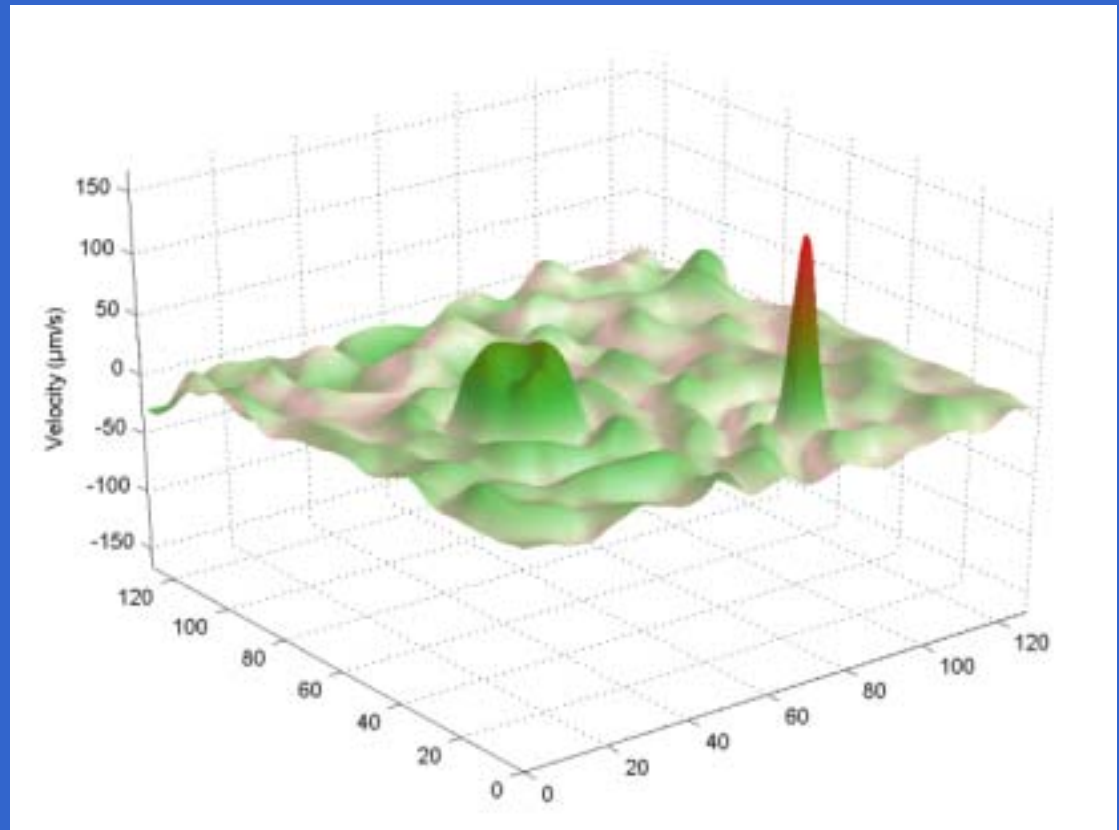
Actual activities: Inclusion of phase information



Intensity



Phase



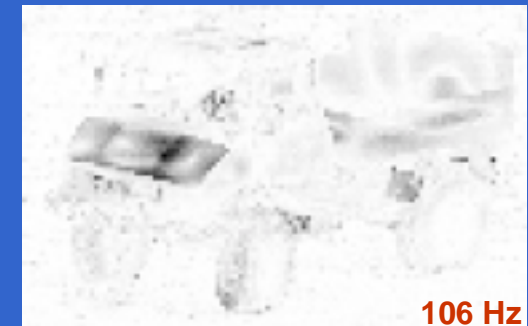
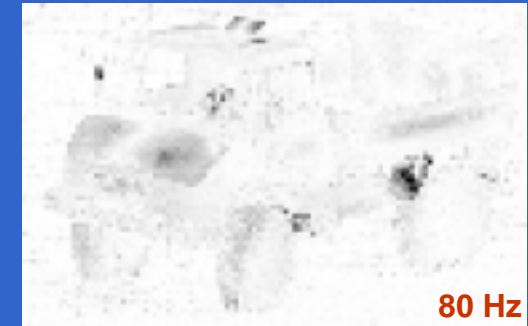
Visualization of soil vibration at 535 Hz

Detection and classification of land vehicles using vibrometry data



■ Maximum
 ■ Minimum

Frequency: 2.5 Hz – 250 Hz

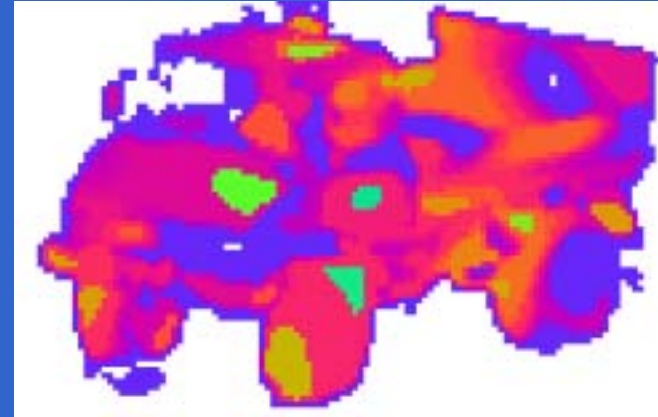


Results of Data Gathering:
Raw Data (Vibration Amplitude)

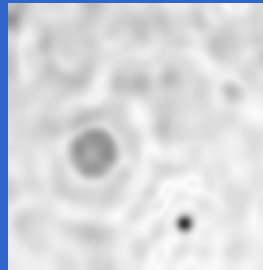
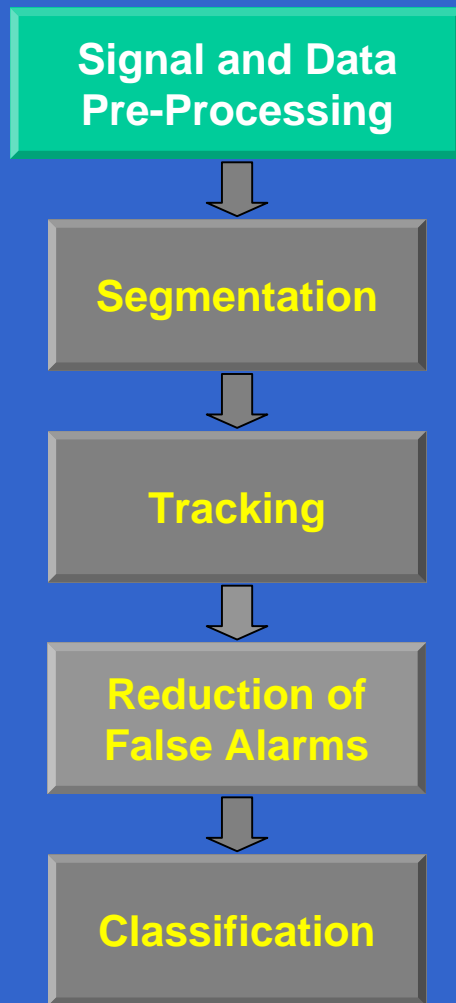
Vibration Energy $\sum_{f_i} v_{\max}^2 \sim E$



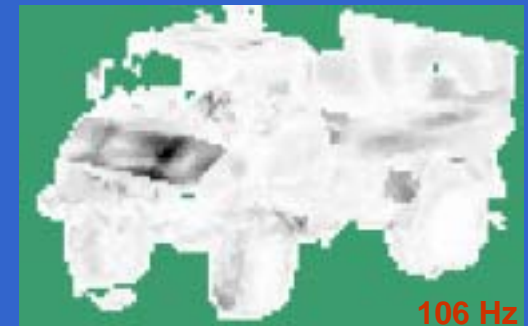
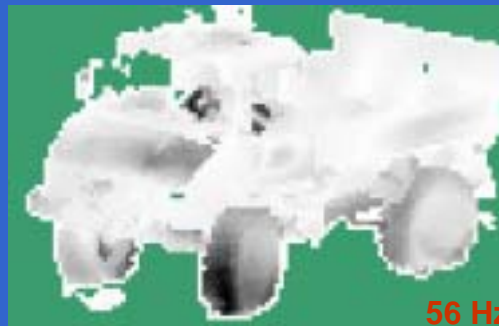
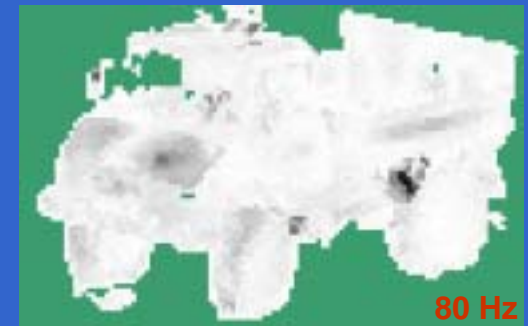
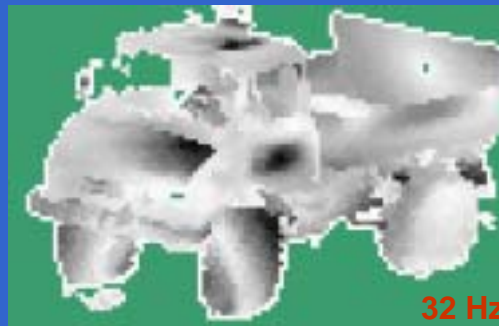
Segmentation



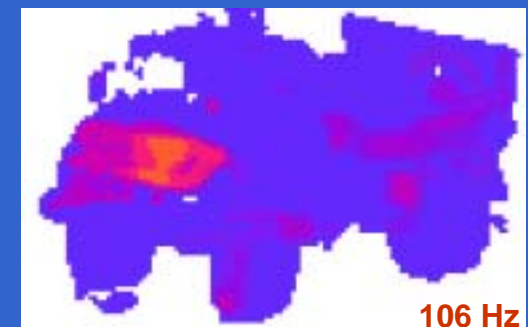
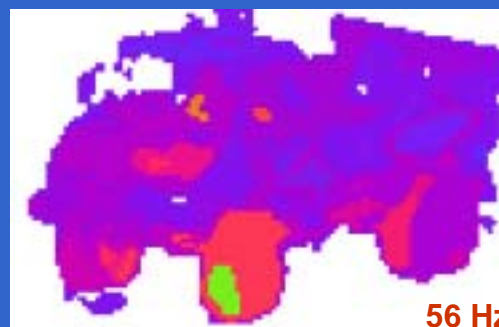
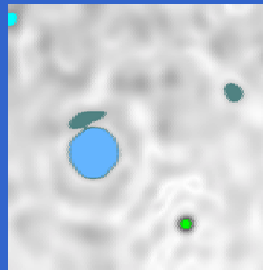
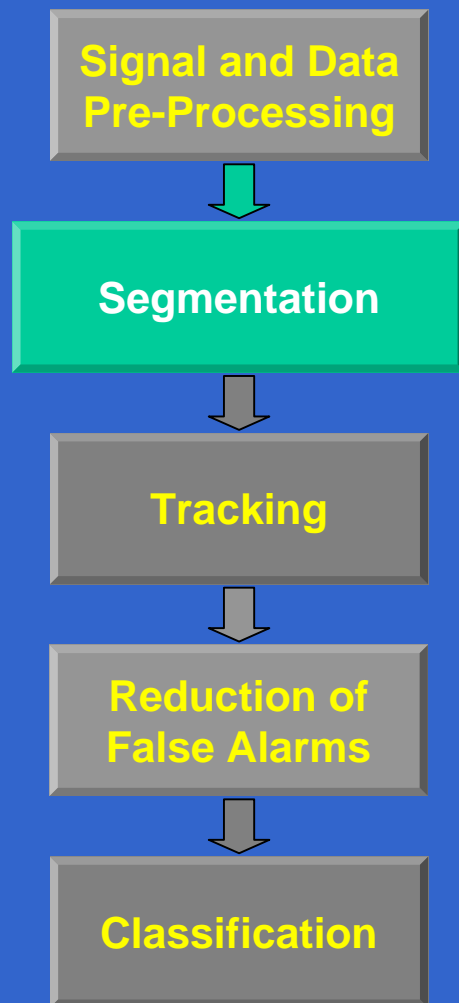
Bitplane used for masking



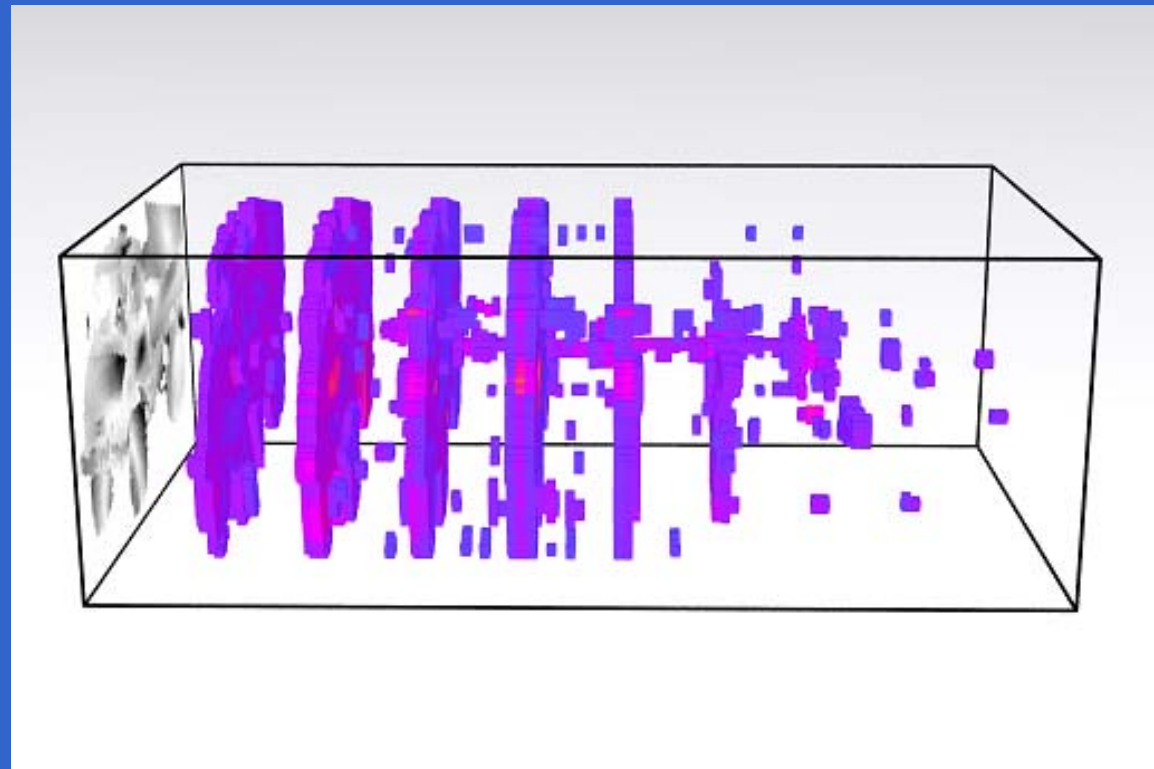
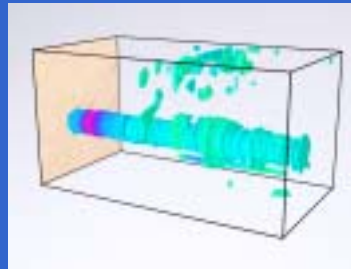
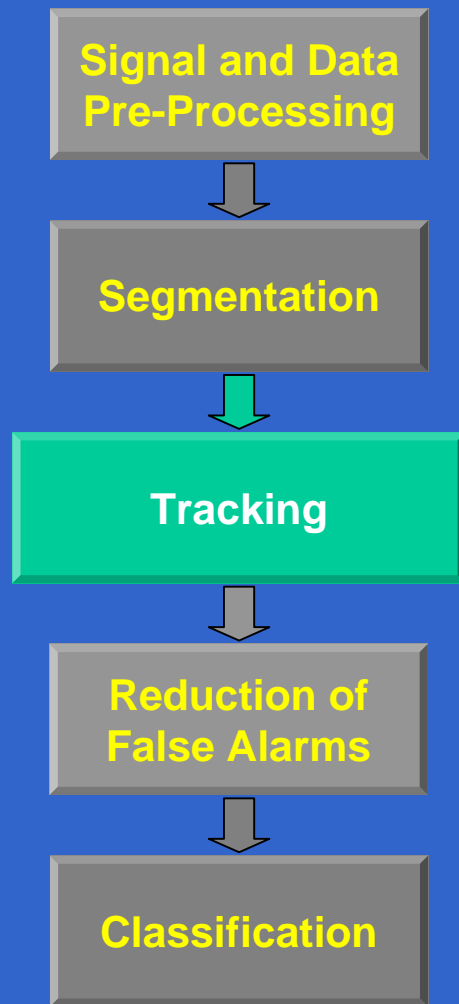
Frequency: 2.5 Hz – 250 Hz



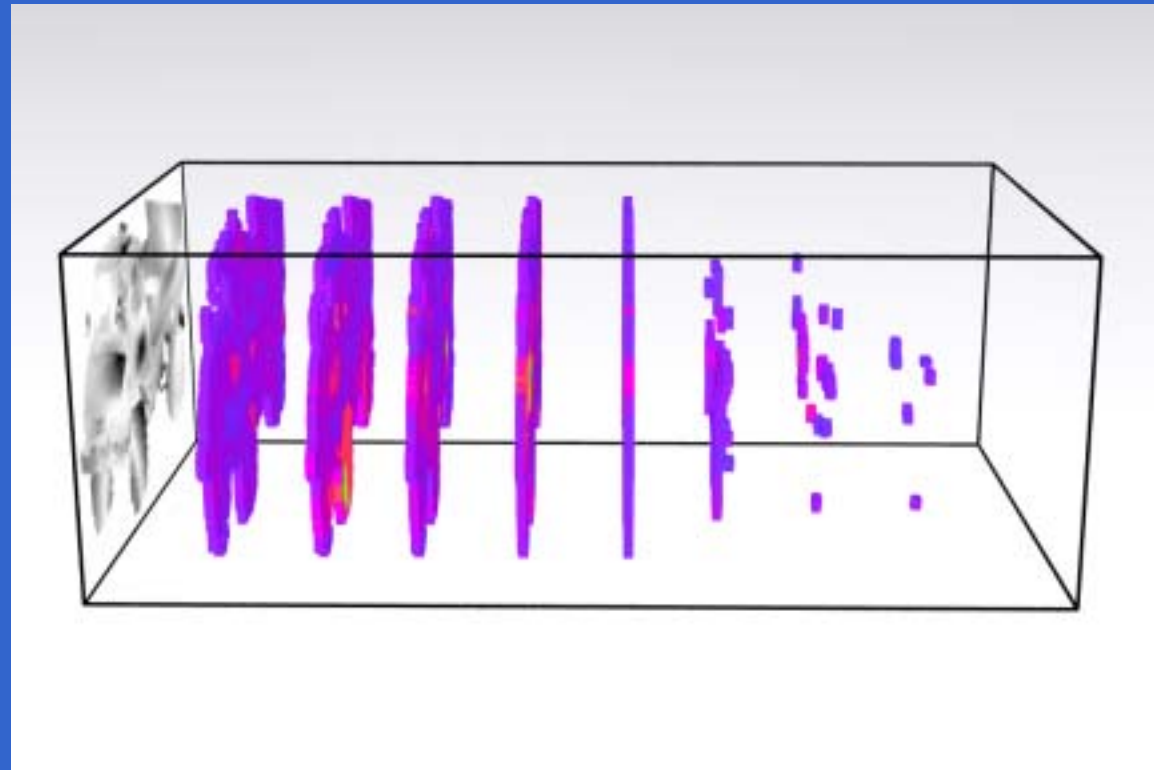
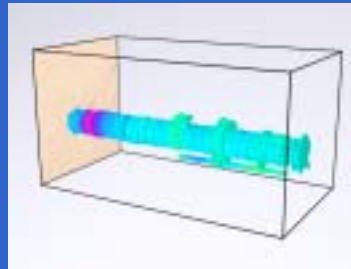
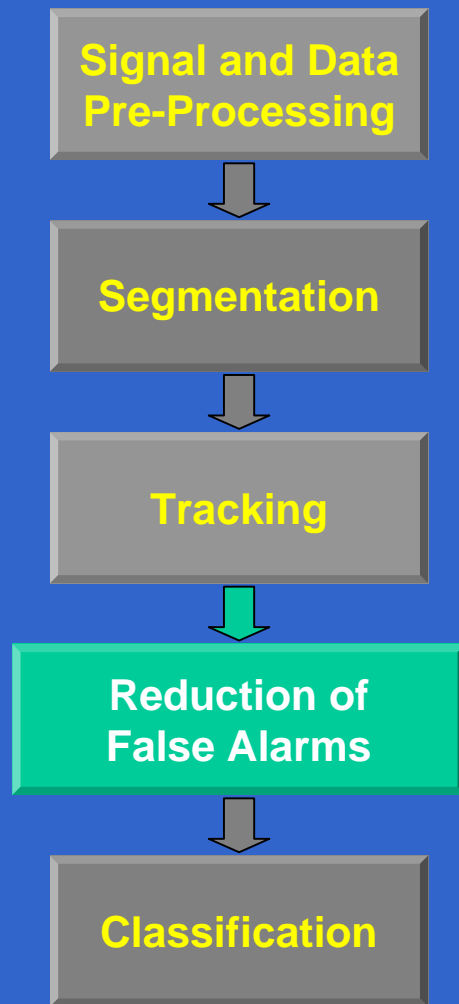
Pre-Processing (eg. Gaussian Low Pass Filter)



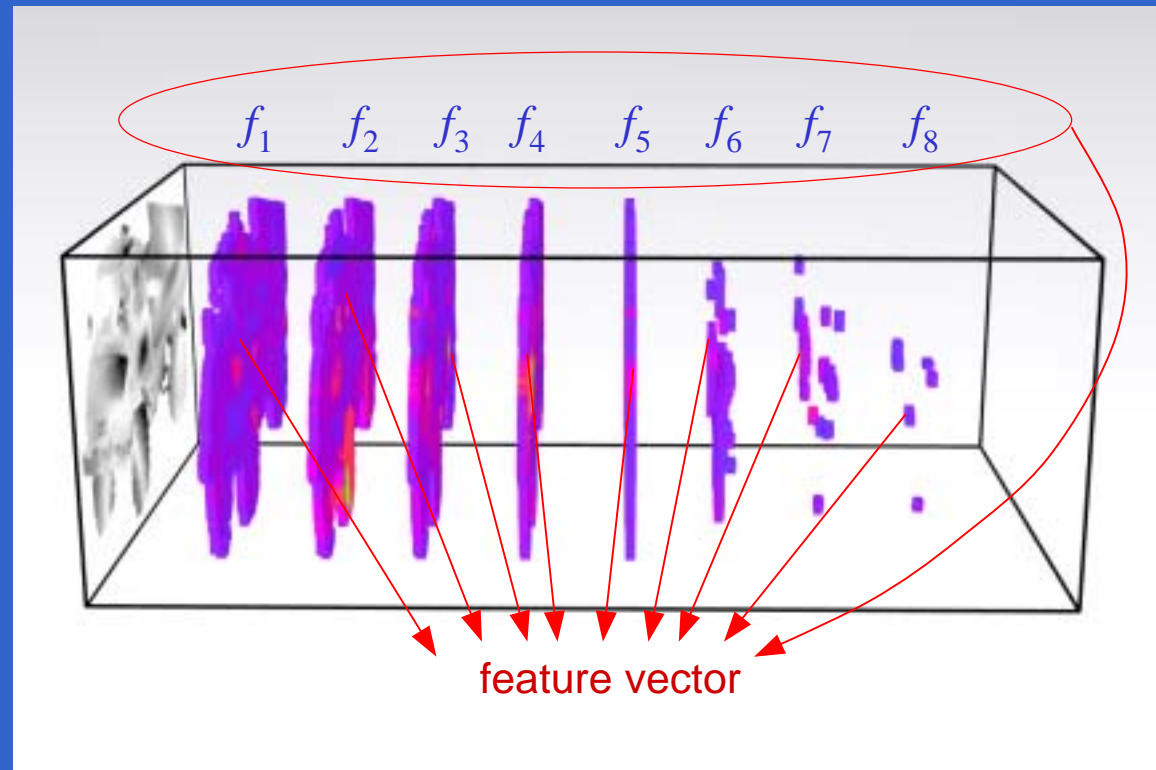
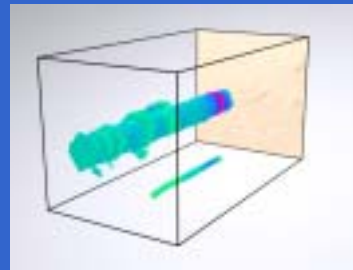
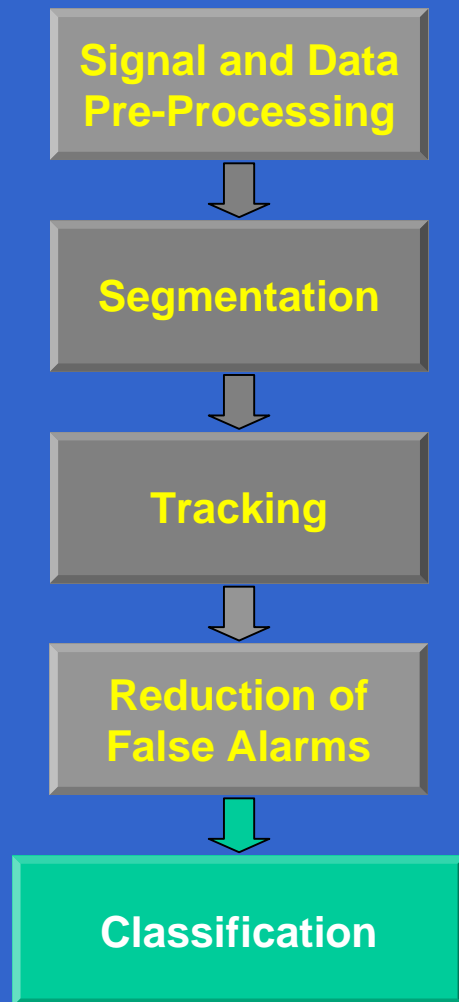
Segmentation by Multi Threshold Analysis



3D-Representation of
Objects with Stability in Frequency



Reduction of False Alarms
(Object Size, Stability of Behavior)



Classification
(Features)

Outlook

- Upgrade of pattern recognition algorithms
- Development of characteristic target features
- Evaluation of further data sets (2d vibration signatures)
- Analysis of background and clutter effects
- Assessment for military applications